

TITLE OF THE INVENTION

**OPTICAL FILTER AND APPARATUS AND METHOD FOR
MONITORING OPTICAL CHANNEL USING THE OPTICAL FILTER**

CLAIM OF PRIORITY

This application makes reference to, incorporates the same herein, and claims all benefits accruing under 35 U.S.C. §119 from an application entitled *Optical Filter And Apparatus And Method For Monitoring Optical Channel Using The Optical Fiber* earlier filed in the Korean Industrial Property Office on the 18th day of January 1999, and there duly assigned Serial No. 1260/1999 by that Office.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a wavelength division multiplexing (WDM) optical communications system, and more particularly, to an apparatus and method for analyzing the spectrum of an optical signal using etalon to monitor a change in the wavelength of a wavelength division multiplexed (WDM) optical signal and the optical signal-to-noise ratio (OSNR) of the WDM optical signal.

Description of the Related Art

Monitoring of WDM optical signals in optical transmission systems is a key technique in wavelength division multiplexing (WDM). The monitoring of an optical signal of each channel as to whether the optical signals operate normally is required to obtain high reliability in optical transmission systems.

Measuring the OSNR of each channel, a change in the wavelength, and the number of wavelengths, which is essential for channel monitoring techniques, is performed by obtaining amplified spontaneous emission (ASE), and the output and wavelength in each channel.

In the prior art, a method of transmitting a dither signal to each channel, a method of using an arrayed waveguide grating (AWG) or a tunable filter which are optical devices, and other commercialized spectrum analyzer techniques are applied to achieve the above measurement.

Precise measurement of a peak value in a wavelength and the OSNR is essential for wavelength monitoring. However, the method of transmitting a dither signal to each channel and monitoring an optical signal in a receiving terminal using a phase locked loop (PLL) cannot obtain a wavelength value. The method using optical devices such as an AWG, a tunable filter, or the like, which can obtain even wavelength values, is quite costly. An optical spectrum analyzer or a multiple wavelength meter, which are used for optical spectrum analysis, is commercialized but expensive, so it is not suitable for channel monitoring. Therefore, there is an increasing demand for a spectrum analyzer which is simple and can be applied to monitor the channels of a WDM optical signal.

A spectrum analysis technique is the fundamental principle for achieving channel monitoring

1 of a WDM optical signal. In existing spectrum analysis techniques using a Fabry Perot tunable filter,
2 the thickness of etalon is varied by an electrical signal, thus deteriorating the accuracy and requiring
3 a controller for variable control.

4 U.S. Patent No. 5,825,792 for a *Wavelength Monitoring and Control Assembly for WDM*
5 *Optical Transmission Systems* to Villeneuve et al discloses a Fabry-Perot etalon structure that
6 provides feedback loop back to the laser source to control the laser source. What is needed is the
7 use of such an etalon structure that interacts with the output of a fiber optic multiplexed signal to
8 discern the spectral components and the optical signal to noise ratio of various wavelengths that may
9 be traveling through an optical fiber.

10 SUMMARY OF THE INVENTION

11 An objective of the present invention is to provide an optical filter which effectively uses the
12 function of etalon, and an apparatus and method for monitoring optical channels using the optical
13 filter, in monitoring a channel signal of a wavelength division multiplexed (WDM) optical signal.

14 It is another object to discern the optical components of a WDM signal and discern the
15 optical signal to noise ratio of each component.

16 To achieve the above objective of the invention, there is provided an optical filter including:
17 an input unit for receiving a wavelength division multiplexed (WDM) optical signal via an optical
18 transmission medium and outputting optical signals that have different incidence angles according
19 to the wavelengths of the optical signals; and a filter for receiving the optical signals from the input

1 unit and separating the WDM optical signal into optical signals having different wavelengths using
2 the difference between resonance lengths according to the different incidence angles.

3 To achieve the above objective of the invention, there is provided an optical channel
4 monitoring apparatus including: an optical filter for receiving a WDM optical signal from an optical
5 transmission medium, making the incidence angle of each wavelength of the WDM optical signal
6 different from each other, and separating the WDM optical signal into optical signals having
7 different wavelengths using the difference between resonance lengths according to the different
8 incidence angles; and a detector for detecting the intensity of each of the optical signals having
9 different wavelengths as an electrical signal.

10 To achieve the above objective of the invention, there is provided an optical channel
11 monitoring method including: receiving a WDM optical signal from an optical transmission medium
12 and outputting optical signals that have different incidence angles according to the wavelengths of
13 the optical signals; receiving the optical signals and separating the WDM optical signal into optical
14 signals having different wavelengths using the difference between resonance lengths according to
15 the different incidence angles; and detecting the intensity of each of the optical signals having
16 different wavelengths as an electrical signal.

17 BRIEF DESCRIPTION OF THE DRAWINGS

18 A more complete appreciation of the invention, and many of the attendant advantages
19 thereof, will be readily apparent as the same becomes better understood by reference to the following

detailed description when considered in conjunction with the accompanying drawings in which like reference symbols indicate the same or similar components, wherein:

FIG. 1 illustrates the principle of a Fabry-Perot resonator;

FIG. 2 is a block diagram of an optical channel monitoring apparatus according to an embodiment of the present invention; and

FIG. 3 is a detailed diagram of FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, which illustrates the principle of a Fabry-Perot resonator which is a component of the present invention, an optical signal having a wavelength of λ is resonated in an etalon and transmitted through the etalon. The optical signal satisfies Equation 1:

EQUATION 1

$$\sin(2\pi L/\lambda) = m\pi \dots\dots\dots (1)$$

wherein m is a positive integer, that is, 1, 2, 3, ... , and L denotes the interval between etalon plates.

In FIG. 1, when optical signals having wavelengths of λ_1 and λ_2 are incident upon the etalon via an optical fiber at different angles, they are transmitted at different angles. The present invention is a spectrum analysis technique using this principle. The principle is based on the fact that the resonance length between two mirrors depends on the incidence angle of light. When a wavelength

perpendicularly applied and transmitted is set to be λ_1 , a predetermined number of wavelengths exist within a resonance length, so that the relationship shown in Equation 2 is established. When light is incident at an angle of θ , the resonance length is increased by Equation 3, and the transmission wavelength λ_2 of an optical signal is given by Equation 4.

EQUATION 2

$$\lambda_1 = \frac{L}{n} \dots\dots\dots (2)$$

wherein n denotes the number of wavelengths within a resonator.

EQUATION 3

$$resonancelength = \frac{L}{\sin \theta} \dots\dots\dots (3)$$

EQUATION 4

$$\lambda_2 = \frac{L}{n \sin \theta} \dots\dots\dots (4)$$

The angle of detection depending on a wavelength which is used in WDM optical transmission systems, can be obtained using Equation 4, as shown in the following Table 1.

Wavelength (nm)	$\theta(^{\circ})$	Wavelength (nm)	$\theta(^{\circ})$
1540.55	90.0	1553.33	82.6
1541.35	88.2	1554.13	82.4
1542.14	87.4	1554.94	82.2
1542.93	86.8	1555.74	82.0
1543.73	86.3	1556.55	81.8
1544.52	85.9	1577.36	81.6
1545.32	85.5	1558.17	81.4
1546.16	85.1	1558.98	81.2
1446.91	84.8	1559.80	81.0
1547.71	84.5	1560.60	80.8
1548.51	84.2	1561.42	80.6
1549.31	83.9	1562.23	80.4
1550.11	83.6	1563.04	80.3
1550.91	83.4	1563.86	80.1
1551.72	83.1	1564.68	79.9
1552.52	82.9	1565.50	79.8

Referring to FIG. 2, a channel monitoring apparatus according to an embodiment of the present invention includes an input unit 200, an optical filter 210, a beam size controller 220, and a detector 230. A WDM optical signal is input to the input unit 200. In the input unit 200, a lensed fiber having a small spreading angle is used at the end portion thereof, and the WDM optical signal is controlled to be incident upon the optical filter 210 at different angles according to wavelength through a cylindrical concave lens. The optical filter 210 separates optical signals received from the input unit 200 according to their wavelengths, and output the same to the beam size controller 220.

1 The beam size controller 220 controls the beam size of optical signals which have passed through
2 the optical filter 210. An optical signal adjusted by the amplifier 220 is applied to the detector 230
3 for converting the optical signal into an electrical signal. The optical signal converted into an
4 electrical signal in the detector 230 is applied to a data processing device such as a microprocessor,
5 and thus the wavelength and the OSNR of the optical signal are calculated.

6 Referring to FIG. 3, which is a detailed diagram of the channel monitoring apparatus shown
7 in FIG. 2, input unit 200 of Fig 2 corresponds to optical fiber 300 and lens 310 of Fig 3 and optical
8 filter 210 of Fig 2 corresponds to etalon 320 of Fig 3. The lens of the input unit receives WDM light
9 through the optical fiber and outputs a plurality of optical signals each of which has a different
10 wavelength and also has a different incident angle to the optical filter. Lens 310, for example, a
11 cylindrical concave lens, allows a WDM optical signal received via an optical fiber 300, to be
12 incident upon a first surface 321 of etalon 320 at various angles. Here, the lensed fiber at the end
13 portion of the input unit collimates incident light, and then the cylindrical concave lens controls the
14 angle of the collimated light. Now, the WDM optical signal is assumed to have been multiplexed
15 with optical signal channels having wavelengths of λ_1 through λ_8 . The optical signals incident upon
16 the first surface 321 at different angles are positioned on a second surface 322 of the etalon 320
17 according to the wavelengths of the optical signal, that is, wavelengths of λ_1 through λ_8 , on the basis
18 of the incidence angles of the optical signals. This shows an application of a phenomenon in which
19 a resonance length within the etalon 320 varies with the incidence angle θ using the principle of a
20 Fabry-Perot resonator. The optical signals separated according to their wavelengths are input to an

infrared photo detector (IR PD) array 340. An optical instrument such as a microscope 330 may be used to adjust magnification of light in order for the IR PD to analyze the focused light. The PD array 340 receives the optical signals and converts the same into electrical signals. Data on the optical signals converted into the electrical signals by the PD array 340 is applied to a data processing device such as a microprocessor, and is used to calculate the wavelengths and the OSNR of the optical signals.

The etalon 320 can prevent different wavelengths from being detected at the same angle, only when a free spectral range (FSR) is thin enough to include channels for WDM.

The FSR with respect to the number of vibrations is given by Equation 5:

EQUATION 5

$$FSR_v = \frac{c}{2nL} \dots\dots\dots (5)$$

wherein c denotes a velocity of light, n denotes a refractive index, v denotes the number of vibrations, and L denotes the interval between plates of etalon.

The FSR with respect to wavelength is given by Equation 6:

EQUATION 6

$$FSR_\lambda = \frac{\lambda}{2nL} \dots\dots\dots (6)$$

wherein c denotes a velocity of light, n denotes a refractive index, λ denotes a wavelength, and L denotes the interval between plates of etalon.

The fineness representing the characteristics of light transmitted through the etalon 320 is defined by Equation 7, and must be great to increase the resolution between wavelengths.

EQUATION 7

$$\text{fineness} = \frac{FSR_{\lambda}}{\Delta\lambda} \dots\dots\dots (7)$$

wherein $\Delta\lambda$ denotes the full width half maximum of a wavelength.

Also, the fineness is a function with respect to a reflective index R as shown in Equation 8, so that it can be seen that the fineness increases with an increase in R .

EQUATION 8

$$\text{fineness} = \frac{\pi\sqrt{R}}{1-R} \dots\dots\dots (8)$$

Calculation of the specification of the etalon 320 will be taken as an example. According to the calculation based on Equations 6, 7 and 8, a 0.8nm 32-channel optical signal, which is used for WDM optical transmission, must have a fineness in which the entire wavelength interval is 24.8nm or greater. Here, on the assumption that the refractive index n is 1.4 and the FSR is 30nm,

1 the thickness of the etalon 320 is calculated to be $28.6\mu\text{m}$. Also, the resolution between wavelengths
2 must be smaller than 0.1nm to be used for channel monitoring in WDM optical transmission
3 systems, so that the fineness associated with the resolution must be increased. Here, when the FSR
4 is set to be 30nm , the fineness must be greater than or equal to 300 to obtain a resolution of 0.1nm .
5 Therefore, it becomes evident that the reflective index of etalon, R, must be greater than or equal to
6 99% to obtain a fineness of 300.

7 Before incident light is input to the lens 310, a lensed fiber is used to prevent the incident
8 light from spreading. Referring to the calculated angles in Table 1, angles of incidence upon the
9 etalon 320 must be at least 10.5° to detect wavelengths of 32 channels. Thus, the incidence angles
10 of light are controlled by the lens 310 such as a cylindrical concave lens. Since optical signals
11 transmitted at different angles are detected by the PD array 340, the etalon 320 must be sufficiently
12 separated from the lens 310 so that the resolution of an optical signal is greater than or equal to
13 0.1nm and a sufficiently large image lands on the etalon 320. When the intensities of optical signals
14 passed through the etalon 320 are weak, the microscope 330 is used.

15 The intensity of light according to wavelengths is calculated by detecting the intensity of
16 light according to the transmitted positions using the PD array 340. At this time, the intensity of a
17 channel having the highest intensity, and the intensity of ASE are calculated, thereby obtaining the
18 OSNR which is the ratio of the intensity of incident optical signals to the intensity of ASE.
19 The distribution of light detected by the PD array 340 via the etalon 320 is calculated in terms of
20 current. Thus, a microprocessor or the like can obtain the wavelength of each channel and the OSNR

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